Fig. 10. *Glyciphagus dispar*. Adult female, first left leg, from above. ×300.
11. —— ——. Adult female, second left leg, from above. ×300.
12. —— ——. Adult female, third left leg, from above. ×300.
13. —— ——. Adult female, fourth left leg, from above. ×300.
14. —— ——. Adult male, first left leg, from above. ×400.
15. —— ——. Adult male, third left leg, from above. ×400.
16. —— ——. Adult male, fourth left leg, from above. ×400.
17. —— ——. Adult male, arrangement of the intromittent organ and surrounding sclerites, &c.

Description of *Strongylus Arnfieldi* (Cobb.), with Observations on *Strongylus tetracanthus* (Mehl.).

By T. Spencer Cobbold, M.D., F.R.S., F.L.S., Hon. Vice-Pres. Birmingham Nat. Hist. and Microsc. Society.

[Read 4th March, 1886.]

(Plate XXXVI.)

It has been commonly taken for granted that all the Nematodes hitherto found to infest the lungs of Solipeds are referable to the species which proves so destructive to young cattle. On the authority of Eichler in the one case and of Gurlt in the other, Diesing states that the cattle Strongyle (*Strongylus micrurus*) infests *Equus caballus* and *E. asinus*. As regards the horse I have verified Eichler's find, but as regards the ass it happens that all the lung-worms carefully examined by me are of a different species. This circumstance does not, of course, disprove the accuracy of Gurlt's position, but rather renders it probable that at least two nematode-species infest the lungs of both hosts.

On the 1st of December, 1882, Mr. Arnfield, at that time a pupil of the Royal Veterinary College, brought me some worms removed from the trachea and bronchi of a donkey. The batch comprised three males and ten females, most of the latter being much injured. Guided by their size and general aspect it was easy enough to suppose that the worms were examples of *Strongylus micrurus*; but a microscopic examination showed that the naked-eye appearances were deceptive. The worm, in fact, was new to science, and it was accordingly named after its discoverer. To secure priority in the finder's favour a brief description followed in the pages of 'The Veterinarian' (Jan. 1884), but no figure of the worm has hitherto been published. Subsequent to

the date above mentioned many other examples were from time to time submitted to my notice,—another pupil, Mr. Hassall, procuring and mounting these worms with much success.

Strongylus Arnfieldi (*Cobb.*).

Mouth simple; œsophagus short, slightly constricted; body with very fine striæ; vulva of the female a little above the anus; tail of male with trilobate hood, rather broader than long; rays complete, posterior ray broad and united to its fellow at the base, bifurcate at the end; mid ray narrow, cleft to the centre; postero-lateral ray long, variable in width; spicules equal, with an accessory piece; tail of female short, sharply pointed. Viviparous. Males 1½ inch long; females 3 to 3½ inches.

Hab. Trachea and bronchi of the ass (*Equus asinus*).

The anatomical points that call for special notice are such as refer to the morphology of the hood and its rays, to the position of the vulva, and to the structure of the embryo. The ray-pattern contrasts strongly with that of *S. micrurus*. I have recently verified Schneider's description of the rays of *S. micrurus*, ray for ray. Unpublished figures in my possession show only a relatively greater length of certain rays than Schneider's original plan suggests. This applies more particularly to the anterior ray. In my specimens of *S. micrurus* the innermost division or cusp of the trifid end of the posterior ray is also more strikingly pronounced. Contrasting the hoods of *S. micrurus* and *S. Arnfieldi*, the disconnected character of entire series of rays at their bases is of itself sufficiently distinctive of the former species; whilst, as regards the individual rays, I need only further refer to the paramount aspect of the posterior ray and its bifid extremity in *S. Arnfieldi*. Equally diagnostic of *S. Arnfieldi* is the position of the reproductive outlet in the female, which is placed above the anus at a distance of only 1 millim. from the end of the tail. In *S. micrurus* the distance is 18 millim. (Schneider). The eggs occur in prodigious numbers, probably in excess of what is seen in *Strongylus filaria* of the sheep, in which species, according to Mr. Beulah, each female carries 300,000 embryo-containing ova. My original estimate for *S. micrurus* was one third of this number. The viviparous character of *S. Arnfieldi* is readily tested by pressure under a cover-glass, when embryos will escape from the vulva. An embryo thus freed already shows a well pro-

nounced intestinal canal, the œsophagus and hind gut being both clearly defined. The mid gut is obscurely cellular in my preserved specimens. Of more interest is the form of the embryo, whose sharp tail supports a distinct, though excessively minute, bristle-like piece at the end. The base of this appendage does not exceed the $\frac{1}{2000}$ of an inch in diameter. It may be added that the presence of a small or third spicule in *S. Arnfieldi* is not distinctive, as I have found a similar arrangement to obtain in *S. micrurus*, which has hitherto escaped observation. The little piece is about $\frac{1}{666}''$ long in the last-named species.

In view of diagnosis the following approximate measurements may be found useful. Diameter of the body of the male $\frac{1}{160}''$, of the female $\frac{1}{75}''$; each large spicule $\frac{1}{100}''$ in length by about $\frac{1}{850}''$ broad; œsophagus of the male $\frac{1}{45}''$ long; anus $\frac{1}{100}''$ distant from the end of the tail; vulva $\frac{1}{25}''$ from the point of the tail; eggs containing coiled embryos $\frac{1}{350}''$ long by $\frac{1}{400}''$ in breadth; free embryos $\frac{1}{100}''$ in length, and rather less than $\frac{1}{2000}''$ in breadth; base of the tail opposite the anus $\frac{1}{5000}''$ broad, and the bristle-like extremity from $\frac{1}{20000}''$ to $\frac{1}{50000}''$ only.

Turning to *Strongylus tetracanthus*, my object is to contribute a few facts towards a more complete knowledge of the structure and development of this common entozoon. What is at present known of its anatomy is chiefly due to Dr. Schneider. The importance of the worm in relation to the destruction of valuable animals is supreme; but inasmuch as Sonsino and others have already quoted my published results on this head, I refer those who are interested in questions of parasitic epizöoty to some of the papers cited below. I may, perhaps, be permitted to add that an exhaustive knowledge of the human parasitic epidemics can only be obtained by the study of similar outbreaks affecting animals; and that in both cases any advances made towards combating the evils thereby produced can only rest upon natural-history facts, especially upon those of development.

On removing full-grown specimens of the four-spined Strongyle from the cæcum or colon of any Soliped, their bright red colour at once betrays the leech-like habits of the parasite. Even the perivisceral fluid itself is tinged. The males and females are of nearly equal size, varying from six to eight lines in length. Prof. Schneider has shown that, in addition to the so-called spines

of the head, there are two papillæ, one on each side of the mouth. These I have also seen. The fore gut has a complicated structure, more strikingly so than has hitherto been stated. The mouth leads to a strong buccal cup, supporting a circular series of short bristles (described and figured by Schneider, but only indicated by a dark line in my drawing), which separately have an extreme length of $\frac{1}{750}$ of an inch. The cup rests upon a muscular ring, which also supports a circular row of small chitinous processes. The ring is succeeded by an anterior œsophageal bulb, the lumen of which is bordered by chitin-plates. Then follows a broad muscular pharynx, through which the narrow chitinous cylinder of the lumen glimmers distinctly, leading down to the somewhat broader posterior bulb, which also displays thick dental plates. By these means an unusually powerful sucking action must result. The fore gut is next succeeded by a broad chyle-intestine marked at the upper part by regular constrictions, due to the presence of muscle-fibres which are connected at their periphery with nucleated muscle-cells that stretch across the perivisceral cavity. The constrictions become less marked towards the lower half of the mid gut, which latter finally ends in a short and narrow rectum, opening in the female at the base of a short conical tail. In some situations fine granules may be seen floating in the perivisceral fluid, and on one side of the œsophagus a particularly well-marked, colossal unicellular gland is visible. Concerning the sexual apparatus of the male I have little to add, except by way of confirmation of the views of Schneider as to the grouping of the rays of the hood. However, it is worth remarking that in examples of *Strongylus tetracanthus*, examined in February 1876, I found the innermost branch of the thrice-divided posterior ray supplied with an offshoot, which, in place of being quite rudimentary, was nearly as long as the primary branch itself. The spicules are narrow, and when retracted are closely applied to each other, so as to look like a single straight rod of uniform thickness. As regards the female sexual apparatus, the uterine horns and utero-vaginal passage were well seen in the example figured, the cavity of the uterus being crowded with ova near the fundus.

Respecting the skin and its appendages, I must explain that the large bristles of the neck described by Schneider were neither seen in the specimen here drawn, nor in any of the numerous

immature worms that I have examined. Figures 10 and 11 were copied from camera sketches.

It is the question of development that possesses chief interest. As Leuckart has pointed out, the young of this species have been frequently confounded with those of *Strongylus armatus*; especially by Colin and Ercolani (quoted below), the latter stating that the worm-capsules reach the size of a bean. Rudolphi first fell into this very natural error. In the spring of 1873 I first became practically acquainted with certain small encysted worms that had been removed from the intestinal walls of a pony by Prof. Williams of Edinburgh. The nature of similar finds had for many previous years puzzled both anatomists and helminthologists. In 1836 the celebrated Dr. Knox, who had received specimens from Professor Dick, pronounced these equine parasites to be "animals similar to *Trichina*." The systematist Diesing named the species *Nematoideum Equi Caballi*; and specimens were subsequently described by Messrs. Littler and Varnell as "extremely small Ascarides." Like others, I committed errors of interpretation, and (noticing differences of tail-contour which I correctly assumed to have sexual significance) regarded the young parasites as representing an independent species, which I provisionally named *Trichonema arcuata*. The error being explained, I yet think that on other grounds it will be convenient to speak of these immature worms as Trichonema-stages of growth, representing one of the biotomes of *Strongylus tetracanthus*.

When animals are largely infested by the larvæ of *S. tetracanthus*, the young worms first enter the walls of the intestine, and then proceed to encyst themselves in such abundance that throughout a great extent of the colon each square inch of the gut often contains fully one hundred immature Entozoa. In a bad case of infection I counted 39 Trichonemes or young Strongyles within the space of one-fourth of a square inch. In mild cases from two or three to a score may be detected. As obtains in Trichinosis, the amount of infection is a fair criterion of the degree of danger to which the host is exposed. There is, however, this difference, that whereas a fatal result may accrue to the equine host from the presence of a few thousands of young Strongyles within the intestinal walls, a similar disaster to the human bearer requires many millions of Trichinæ within the voluntary muscles. This is not an occasion on which to deal with pathological phenomena;

but as illustrating one step in the migratory process, I may mention that many of the larger and more superficially placed cysts display lesions of their walls, the young worms already protruding their heads. In short, I have taken them, as it were, in the very act of immigrating to the lumen of the intestine whence they had originally emigrated. Without detailing the pathological processes thus set up, it is sufficient to say that they afford irrefragable proofs of the dangerous character of this entozoon.

In any portion of a much-infested intestine it is usual to observe variations in the size of the cysts, each of which contains a single worm. As in some cases the sizes form natural groups, it is clear that the equine host may be infested by successive broods. Variations of structure are seen in the growing larvæ, but in the earliest encysted stage a well-formed intestine is invariably present. One of the smallest worms that I measured was only $\frac{1}{10}$ of an inch in length by $\frac{1}{130}''$ in breadth. In the advanced stage, in which condition the worm is about to re-enter the lumen of the host's intestine, one observes a distinct oral ring, a funnel-shaped buccal cup, a muscular œsophagus with the usual chitinous cylinder, and a strongly pronounced mid gut, presenting constrictions throughout the chylous portion and everywhere walled-in by large nucleated cells that are most conspicuous towards the rectum. Although thus far no structural differentiations mark the presence of internal sexual organs, the sharp-pointed tails of some of the worms and the short conical tail of others already point to differences of sex. The immature character of the worms was recognized by me from the first, but, as already implied, I was unable at the time to refer them to any of the hitherto known species*.

In Helminthology one must always be prepared for surprises.

* In 1831 Gurlt had recognized the circumstance that "die jungen Würmer liegen zusammengekrummt in der Substanz der Schleimhaut, wo sie wie scharze Punkte erscheinen." He spoke of two varieties of the sexual worm, and remarks:—"Auch die kleinere Varietät findet man in der Begattung." The largest of my so-called Trichonemes correspond in size with Gurlt's smaller variety of the adult worm, but as I never saw them in the condition he described they can hardly be the same. Dr. Krabbe's description of the cyst is similar to that of Gurlt, but he makes no mention of the helminthiasis thus produced. [For references, see Literature quoted below.—T. S. C.]

Thus on the 27th of February, 1874, I received from Mr. W. Cawthron, V.S., of Hadlow, a box holding forty little "cysts or bladders, each containing a worm." These cysts, as Mr. Cawthron termed them, were removed by him from fæces passed by a two-year old colt, together with Oxyurides and large Ascarides, from the presence of which the animal was suffering and rapidly "wasting away." Microscopic examination satisfied me that these so-called cysts were really fæcal pellets, the particles of which had been collected and held together by exudation from the young worms. The vegetable débris thus collected formed a kind of cocoon whose walls were made chiefly of vegetable parenchyma, as shown by plates of muriform and polygonal cells, chlorophyll, spiral vessels, and even raphides. Vegetable hairs and fibres also projected from the surface, here and there. Averaging the size of ordinary pills, some of the cocoons displayed the heads and tails of the enclosed worms standing out as finger-like processes. From one of these coccoons the projecting tail of the worm still retained a part of an old skin which the larva had not fully cast. I have reproduced a small drawing of this singular formation (fig. 15, Plate XXXVI.). In the history of the development of the Nematoids I know of nothing comparable to this cocoon-forming habit of *Strongylus tetracanthus*; and I venture to suggest that we have here a mechanical contrivance which possibly supersedes the necessity of the parasites seeking entrance to the body of an intermediary host. Be that as it may, the cocoon serves as a protecting covering whilst the young worm undergoes partial metamorphosis, attended with ecdysis. Internally, however, there were no visible traces of sexual differentiation. In one worm I noticed minute prominences which I supposed to be rudimentary cephalic spines. Within the pellets a hollow tube corresponds with the form of the enclosed larva, but I did not find any skin-cast within this cavity. Whether my interpretation of the facts be correct or not, future investigations must determine. A missing link, representing a transition from the cocoon-stage to the young and unimpregnated sexual worm, is still wanting to complete the chain of evidence; and it may turn out that a natural expulsion of the cocoons by the host is a necessary provision to this end. The immature females in the most advanced stage prior to impregnation display large numbers of ovarian ova. I believe, however, that all the final stages of growth occur within the bowel of the

equine bearer. If this be so, the following conclusions, partly based on analogy, cannot be far from embracing the whole truth:—(1) The eggs are expelled from their parent in a state of fine yolk-cleavage. (2) The embryos are formed after egg-expulsion, and in a few days escape from their envelopes, undergoing a primary change of skin in moist earth during warm weather. (3) As rhabditiform Nematoids they enjoy a more or less prolonged existence, probably living many weeks in this state. (4) In all likelihood an intermediary host is unnecessary. (5) The rhabditiform larvæ are passively transferred to their equine bearer, either with cut fresh fodder, or whilst the animals are grazing. (6) Passively transferred to the intestinal canal, they thence enter the walls of the cæcum and colon, encyst themselves, and (according to Leuckart) undergo another change of skin. (7) Their presence in the intestinal walls is associated with pathological conditions which frequently prove fatal to the bearer, sometimes creating severe epizöoty. (8) Ordinarily the young worms perforate their cysts and immigrate to the lumen of the bowel, where they already afford external indications of sex (Trichonema-stage of growth). (9) They next form cocoons by the agglutination of vegetable débris within the gut, and undergo a third ecdysis attended with intestinal metamorphosis. (10) The formation of the internal sexual organs and the completion of the definitive form is accomplished within the colon of the host.

The literature of this species is as follows:—

Rudolphi.—(Proles Strongyli armati.) Entozoorum Hist. Nat. vol. i. p. 207 (1808–10).

Mehlis.—(*S. tetracanthus*) in Isis, 1831, p. 79 (quoted by Gurlt).

Gurlt.—(Vierstacheliger Pallisadenwurm.) Lehrb. d. path. Anat. der Haus-säugethiere, Bd. i. p. 355. tab. vi. figs. 23–32 (1831).

Knox.—Remarks on the lately discovered Entozoa infesting the muscles of the human body; with some observations on a similar animal found beneath the intestinal membrane of the horse. Edinb. Med. & Surg. Journ. vol. xlvi. p. 92 (1836).

Dick.—(Worms at different stages of growth.) Quoted by Dr. Knox.

Miescher.—Bericht üb. d. Verhandl. d. nat. Gesellsch. in Basel, Bd. iii. p. 5; Ann. d. Sci. Nat. tom. x. p. 191 (1838); and Wiegm. Arch. f. Naturg. 1839, 5 Jahrg. Bd. ii. p. 159.

Dujardin.—(*Sclerostoma quadridentatum*) Hist. Nat. des Helm. 1845, p. 258.

Diesing.—(*Sclerostomum tetracanthum*) Syst. Helm. vol. ii. p. 305 (*Nematoideum Equi Caballi*), p. 332 (1851).

Ercolani.—Giorn. d. Vet. 1852, t. i. p. 317 (quoted by Leuckart).

Molin.—(*Cyathostomum tetracanthum*) Il sottard. degli Acrofalli, 1860, pp. 453–455, tav. xxv. figs. 5, 6.

Colin.—Mém. sur le dévelopg. et les migrations des *Sclerostoma*, 1864 (quoted by Leuckart).

Varnell.—(Entozoa in various stages of growth.) The Veterinarian for 1864, pp. 202 and 265.

Littler.—(Extremely small Ascarides.) Quoted by Varnell, as above, 1864.

Schneider.—Monog. d. Nemat., p. 134, tab. viii. figs. 7, 8 (1866).

Krabbe.—Husdyrenes Involdsorme, p. 17; Aftryk af Tidsskr. for Veterin., 1872.

Cobbold.—Observations on rare Parasites in the Horse. The Veterinarian, March 1875.

——. Further remarks on rare Parasites from the Horse. *Ibid.* May 1874.

——. Fatal epidemics affecting Ponies. *Ibid.* June 1874; also in 'The Field' for April 25, 1874.

——. Epizöoty in the Horse, more especially in relation to the ravages produced by the four-spined Strongyle. The Veterinarian, April 1875.

——. Parasites of the Horse. (Note on specimens of *S. tetracanthus*.) *Ibid.* March 1876.

——. 'Parasites' (of Solidungula). London, 1879, p. 374 et seq. (with figs.).

Leuckart.—Die menschl. Par., Bd. ii. 1876, p. 445 (with fig.).

Sonsino.—On the Entozoa of the Horse in relation to the late Egyptian equine plague. The Veterinarian, March 1877.

Linstow, O. von.—Compend. d. Helm., p. 56–7 (1878).

DESCRIPTION OF PLATE XXXVI.

Fig. 1. Head and neck of *Strongylus Arnfieldi*. Male. × 65 diam.
2. Tail and lower part of the body. Female. × 65 diam.
3. Front view of the same.
4. Tail and lower part of the body. Male. × 65 diam.
5. Tail of the same, seen from behind. × 180 diam.
6. Plan of the expanded hood and rays, seen from behind.
7. Egg of *Strongylus Arnfieldi* with contained embryo. × 200 diam.
8. Head and neck of the embryo. × 400 diam.
9. Tail of the same, × 400 diam., with (*x*) appendage separately drawn, × 1000 diam.
10. Head and neck of *Strongylus tetracanthus*. Mature male. Highly magnified.
11. Tail of the same species. Female. Highly magnified.
12. Portion of the intestine of a colt, showing cysts beneath the mucous membrane, each containing a worm. Slightly enlarged.
13. One of the cysts containing a larva of *Strongylus tetracanthus* in the Trichonema-stage. × 30 diam.
14. Group of cocoons or fæcal pellets containing immature worms. Natural size.

Fig. 15. One of the cocoons, showing a protruding larva which is undergoing ecdysis. Part of the old skin (*x*) is retained above the tail. × 3 diam.

m, mouth; *sp*, spines; *bc*, buccal cup; *br*, buccal ring; *f*, funnel; *db*, dental bristles (position of); *ph*, pharynx; *rf*, radial fibres; *ab*, anterior bulb; *pb*, posterior bulb; *chp*, chitinous plates; *cht*, chitinous cylinder; *cst*, chyle stomach; *l*, lumen of mid gut; *a*, anus; *ap*, anal prominence; *i*, intestine; *r*, rectum; *gstc*, gastro-intestinal gland-cells; *mb*, muscular bands; *mc*, muscle-cells; *c*, corpuscles; *sp*, spicules; *h*, hood; *rl*, right lobe; *ll*, left lobe; *thl*, third or middle lobe; *ar*, anterior ray; *alr*, antero-lateral ray; *mr*, middle ray; *plr*, postero-lateral ray; *pr*, posterior ray; *v*, vulva; *vg*, vagina; *e*, eggs; *int*, integument; *cu*, cuticle; *d*, dermis; *st*, striæ; *cgc*, colossal gland-cell; *cn*, cell-nucleus; *u*, uterus; *uh*, uterine horns; *ovt*, ovarian tube.

Notes on Entomostraca collected by Mr. A. Haly in Ceylon.

By George Stewardson Brady, M.D., F.R.S., F.L.S., C.M.Z.S.

[Read 17th December, 1885.]

(Plates XXXVII.–XL.)

The Entomostraca here described belong to two sets of gatherings, one from fresh, the other from salt, water. The freshwater species were all taken at Colombo, but of the exact localities no record has been forwarded to me. The marine species, described in Part II. of this paper, were dredged in a depth of 2 fathoms off Calpentyn, in the Gulf of Manaar. For all of them I am indebted to the kindness of Mr. A. Haly, of the Colombo Museum.

Of the freshwater species, especially the Copepoda and Cladocera, the chief interest lies in their very near approach to well-known European species,—all the genera being represented in Northern Europe by species very closely resembling those of Ceylon. Amongst the Ostracoda is a curious form, for which I have thought it right to propose a new generic name, *Cyprinotus*. And, lastly, I have been able to add a little to the descriptions already given by Dr. Baird of two species, *Cypris cylindrica* (*C. Malcolmsoni*) and *C.* (*Chlamydotheca*) *subglobosa*.

The marine species are scarcely of so much interest. They include no new genus, but several new species are described, and some which have hitherto been only imperfectly known are, I think, placed on a more secure footing.

1–9. STRONGYLUS ARMEN

10–15. S. TETRACAN HUS.